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A POWER ELECTRONIC REVOLUTION

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Lieutenant Badorf's paper won The Naval Submarine League Essay Contest while a student at the Submarine Officers Advanced Course 97060.

Introduction

The ability of the Navy to integrate current technology into shipboard systems is a hotly debated question. Unfortunately, we have not completed the task very effectively in recent years. Plagued by manpower and budget reductions, the Navy's constant state of flux has left it struggling to keep up with operational commitments. However, an obligation exists to our sailors to provide them with the best tools to carry out their mission. In addition, the American public deserves the most capable fleet available for their protection and money. To accomplish these aims, Department of Defense (DoD) initiatives like the Dual-Use Applications Program (DUAP) have been undertaken to leverage commercial research, technology, and products into military systems. One of the most promising projects sponsored under DUAP is the Power Electronic Building Block (PEBB) concept. Overseen by the Office of Naval Research (ONR), PEBB is a programmable power module capable of meeting a variety of power conversion tasks. Applied to submarines, PEBB will revolutionize shipboard power distribution by improving platform reliability and survivability in conjunction with significant weight and space savings over traditional AC networks.

PEBB Concurrent Engineering

Throughout the Cold War, the DoD drove technological development in the United States. Following World War II, the utility of advanced weapons systems provided the DoD with a counterbalance to Soviet numerical superiority. As a result, technological breakthroughs were always being made to keep weapons systems current. When the Berlin Wall fell, however, the apparent threat to the United States evaporated. In addition, the American public demanded DoD procurement reform as reports to $700 hammers made headline news. The resultant impact of these occurrences, combined with downsizing, forced the DoD to find ways to pursue acquisition reform under former Secretary of Defense Perry.

DUAP emerged as a product of the reform measures. Implementation of DUAP allows the Navy to pursue shipboard application of the PEBB concept in a cost effective manner by capitalizing on commercial sector developments in electronic power. The process, known as concurrent engineering, gives the Navy the opportunity to lower its R&D overhead and benefit from the latest technology breakthroughs. Commercialization of PEBB also ensures rapid development since market interest exists outside the military. Finally, mass production and supply of PEBB gives the Navy reduced procurement costs and a readily available source of stock–commercial-off-the-shelf concept at its best.

PEBB Background

In the early 1990s, advances in semiconductor manufacturing technology allowed for the production of rugged, high power density switching devices. Coupled with improvements in digital control techniques. PEBB came to being. The basic construction of a PEBB module includes switching devices, control circuitry, and filter elements. The design leads to the fundamental versatility of PEBB. In concept, all the power modules within a particular electrical rating are the same. Thus, as long as sizing is correct, one power module can be substituted for another. The PEBB module receives its particular identity only when software is loaded in the control circuitry. In effect, a user with limited electronics knowledge can construct a reliable power distribution network on the first try. All the user must do is choose the proper sized *blocks* for the application, connect them together, and program them accordingly. In its final form, the user would employ a PEBB network by selecting the desired power conversion function either locally or remotely. Programs resident in the control circuitry would then align and run the switching devices to achieve the desired output.

With the advent of PEBB, the Navy's focus has shifted to employing a DC zonal electric distribution (DC ZED) system on its newest platforms–most notably the Surface Combatant for the 21st Century (SC-21). The DC ZED implementation not only eliminates large AC transformers and mechanical switching devices but also reduces miles of cable runs into two main DC feeders. As a result, the system design achieves significant space and weight savings. More importantly, compartmental auctioneering and fewer bulkhead cable penetrations serve to enhance platform survivability. Combining these factors with PEBB's low maintenance requirements produces a power distribution system suitable for submarine application.

The proposed architecture of the DC ZED system is shown in Figure 1. In this distribution network, AC or DC source(s) supply the main DC feeders. An AC source and its associated rectifier bridge are shown for illustration purposes. The unregulated DC power is distributed via port and starboard busses from the source(s) into designated zonal areas throughout the ship. Each zone contains PEBB modules programmed as either Ship Service Converter Modules (SSCMs) of Ship Service Inverter Modules (SSIMs). The SSCM is used in each zone to step-down the distribution bus voltage to a regulated DC level for use in the Zone. In this way the SSCM inserts intelligence into the system by action to buffer, pre-regulate, and fault protect each zone.

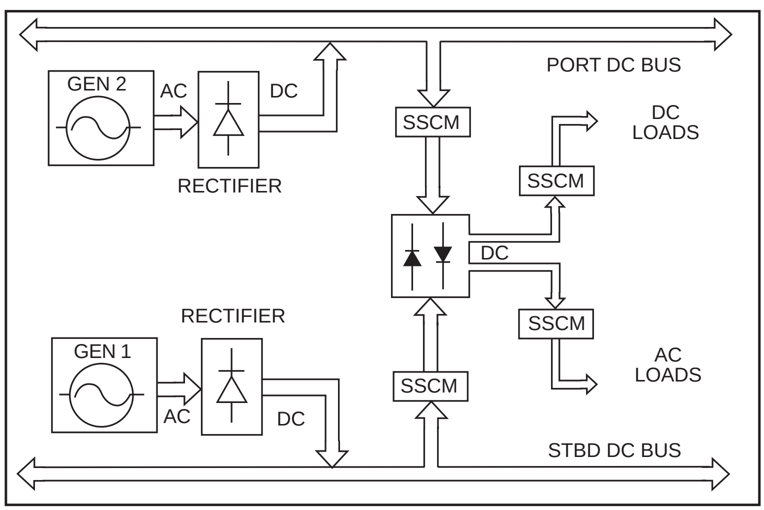

Figure 1. Integrated Power System

Electric loads within the zone are fed by either SSCMs or SSIMs depending on the load's requirement for DC or AC power respectively. Specific advantages resulting from the design include:

- ease of maintenance/troubleshooting due to component modularity
- enhanced power continuity due to auctioneering
- improved watertight integrity due to fewer and smaller bulkhead penetrations

This list is by no means all-inclusive but serves to highlight the most significant features of the DC

ZED system.

Conclusion

Once fully operational, PEBB power conversion devices will form a vital cornerstone in the development of naval electronic systems. As such, application in the submarine environment logically follows due to PEBB's weight, size, and survivability advantages. Based on concurrent engineering, PEBB development is a cost effective solution to DoD and Navy budget constraints. Additionally, the program will serve as a benchmark for commercial-off-the-shelf implementation. Truly, and *electronic revolution* is at hand, and PEBB is leading the way.

REFERENCES

1. Blalock, H.C., "Power Electronic Converter Simulation, Real Time Control and Hardware-In-The-Loop Testing for a Shipboard Integrated Power System." Electrical Engineer Thesis, Naval Postgraduate School, Monterey, CA, March 1995.